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PARAMETER SIGMOID TRANSFORM CONTRAST ENHANCEMENT FOR DENTAL RADIOGRAPH CLASSIFICATION AND NUMBERING SYSTEM

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Abstract

Dental record is one of the ways to identify human identity. Identification requires a system, which is able to recognize each human tooth automatically. Teeth and gums becomes an important issue because they have a high similarity in a dental radiograph image. This similarity tends to influence the segmentation error. This paper proposes a new contrast enhancement by using parameter sigmoid transform to improve the segmentation accuracy. The five main steps are: 1) preprocessing to improve the image contrast using our proposed method, 2) teeth segmentation using horizontal and vertical integral projection, 3) feature extraction, 4) teeth classification using Support Vector Machine (SVM) and 5) teeth numbering. Experimental results using our proposed method have an accuracy rate of 88% for classification and 73% for teeth numbering.

Keywords: *contrast enhancement, dental radiograph, parameter sigmoid transform.*

Abstrak

Data rekaman gigi adalah salah satu cara untuk mengidentifikasi manusia. Pengidentifikasian membutuhkan sebuah sistem yang mampu mengenali tiap gigi secara otomatis. Intensitas gigi dan gusi yang hampir sama menjadi masalah utama pada citra dental radiographs karena dapat mengakibatkan kesalahan dalam proses segmentasi. Pada paper ini diusulkan sebuah metode perbaikan kontras yang baru dengan menggunakan *parameter sigmoid transform* untuk meningkatkan keakuratan hasil segmentasi. Lima tahapan utama yaitu: 1) praproses untuk memperbaiki kontras gambar menggunakan metode yang diusulkan, 2) segmentasi gigi menggunakan *horizontal* dan *vertical integral projection*, 3) ekstraksi fitur, 4) klasifikasi meggunakan *Support Vector Machine* (SVM) dan 5) penomoran gigi. Hasil eksperimen menggunakan metode yang diusulkan menunjukkan tingkat keakuratan hasil klasifikasi sebesar 88% dan penomoran gigi sebesar 73%.

Kata Kunci: *contrast enhancement, dental radiograph, parameter sigmoid transform.*

1. Introduction

Biometric identification has been used as a major tool in forensic identification by law enforcement agencies over the last few decades. Some physiology-based biometric recognition and behavioral characteristic such as face, voice, and iris identification can provide good results in its application. In severe case form of identification that is done more than a week or mass accident (e.g. plane crash) physiological biometric often cannot be used towards parts of the body that have been damaged. But there are other parts of the body that are not easily damaged and strong enough to be used as a postmortem biometric identification. Because of their survivability, the best candidates for postmortem biometrics identification are dental features [1].

In the field of forensics, one of the ways that can be used to identify the identity of human is by collecting data obtained from his/her teeth. Teeth are one part of the human body that stores identity information. Human identification using dental characters is reliable in certain situations, such as natural disasters (tsunami), burns, drowning and victims of other accidents. Teeth features not only as individuals unique characters for identification but also remain unchanged with time due to their natural resistance to decompose as opposed to tissue based on the organs such as eye iris and finger print [2].

For human identification, classification of the teeth becomes an important phase because every person has different teeth information. Therefore, the classification should be done with the extraction of the tooth-related information, which in

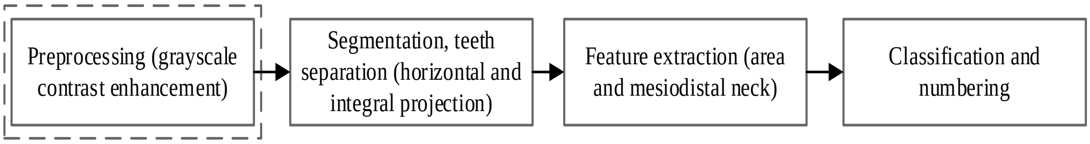


Figure 1. Dental classification and numbering system.

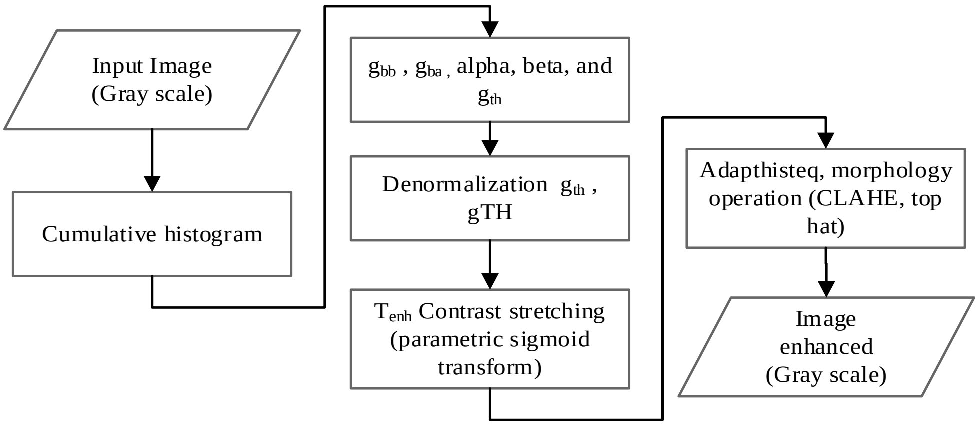


Figure 2. Contrast enhancement process.

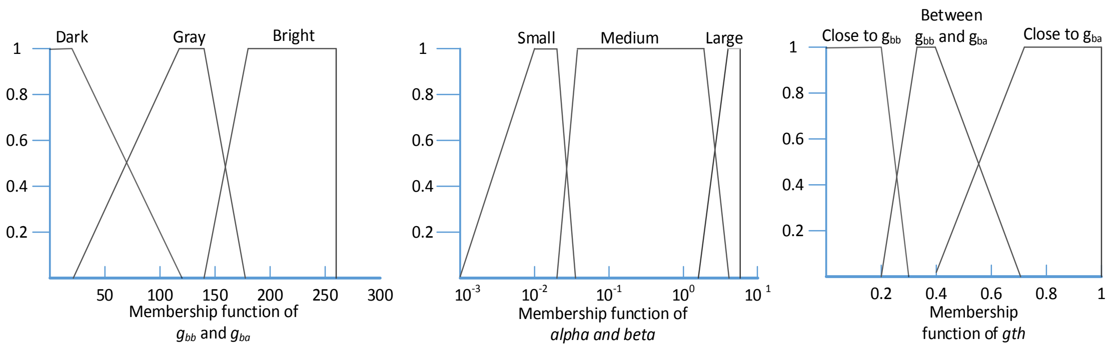


Figure 3. Membership function of parameter transformation.

this system will be used molars and pre-molars. In order to get the classification result accurately, it is also required an accurate segmentation as well [3].

Teeth classification method has been suggested widely earlier. The method used to classify and give number the teeth by using SVM is based on information area and the tooth relative length [4]. Then proposed a method to classify and give number the teeth by using SVM based on information area and mesiodistal width of the teeth [5]. However, there are few images that are not perfectly segmented then resulting lack of valid classification. It will reduce the classification accuracy of the system.

One of the problems that caused difficulties in image segmentation is uneven illumination and poor contrast of the dental radiographs image. Based on the research from some dental radiography which has a varying brightness and contrast level, contrast stretching transformation is conducted by selecting a lower bound and upper bound of the cumulative histogram corresponding to the gray scale image input [6]. Since dental images have low contrast and uneven illumination, it is difficult to do segmentation.

In this paper, we propose a new contrast enhancement by using parameter sigmoid trans-form to improve the accuracy of segmentation results. This method can solve the teeth intensity problem which has similarity to gums and the segmentation results can be obtained accurately. This method is quite simple but it can give good contrast enhancement results that improve the accuracy of seg-

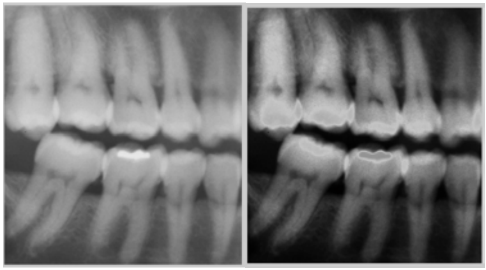


Figure 4. Original image and result of parameter sigmoid contrast enhancement.

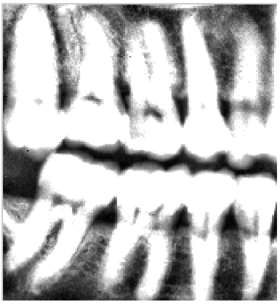


Figure 5. Result of image enhancement.

mentation results. The accurate segmentation result will effectively influence the classification results to be more accurate. These systems can be used in the field of forensic to assist in identifying the identity of the human.

2. Methodology

There are several steps will be conducted (Figure 1). Preprocessing is the most affected step for getting success in segmentation result. Intensity of gums and teeth which are almost the same cause failure of segmentation when performed binarization directly. Therefore, the parameter sigmoid transform method, CLAHE and top-hat operation are used to increase the contrast between the gums and teeth (Figure 2).

Teeth Preprocessing and Segmentation

Contrast Enhancement

In this research we used a method of dental radiography in gray scale image enhancement by implementing a contrast stretching stage. Contrast stretching method is used to get a new image with better contrast than the original image. Contrast stretching is an image enhancement method by stretching the range of intensity values to improve the contrast in an image.

TABLE 1
FUZZY CONTRAST STRETCHING DECISION [6].

	g_{ba} is dark	g_{ba} is gray	g_{ba} is bright
g_{bb} is dark	α is small β is large g_{th} is closed to g_{bb}	α is small β is medium g_{th} is closed to g_{bb}	α is small β is small g_{th} is between g_{bb} and g_{ba}
g_{bb} is gray	Null	α is medium β is medium g_{th} is between g_{bb} and g_{ba}	α is medium β is small g_{th} is closed to g_{ba}
g_{bb} is bright	Null	Null	α is large β is small g_{th} is closed to g_{bb}

In the image of the teeth that we use there are two main issues, the tooth that has a very high intensity (dental works) and part of the image of teeth that has an intensity that is almost the same as the gums. Two of these problems are difficult to handle if only using a simple threshold because they have different intensity. Therefore by using fuzzy logic in contrast stretching process it is easier to overcome.

Contrast stretching method by using a parametric sigmoid transformation is a method which used to change the contrast of the pixel values of the original pixel by mapping the input gray scale g to function $T\_Enh\ (g,\alpha,\beta,g\_th\ )$.

Contrast stretching process is defined in equation(1) [6]. g_{min} and g_{max} is a pixel which has a minimum and maximum intensity of the input gray scale image. g_{th} is a threshold that located between the lower bound g_{bb} and upper bound g_{ba} were selected based on the cumulative histogram input gray scale image. α and β are factors of compression and expansion of the region, gTH is a new proportion of g_{th} in the range [0,255] which is expressed in the equation(2). While g_{bb} and g_{ba} value obtained by equation(3). S_i is cumulative histogram of gray scale in the input image. This study uses parameter κ_1 = 0.6 and κ_2 = 1 that are based on the experiment using our data sets dental radiography which has variety of bright-ness and contrast levels.

$$T_{Enh} = \begin{cases} \left[gTH * \frac{e^{\frac{\alpha(g-g_{min})}{g_{th}-g_{min}}}-1}{e^{\alpha}-1} \right], g_{min} \le g \le g_{th} \\ \left[gTH + (255 - gTH) * \frac{e^{\beta(g_{th}-g)/(g_{max}-g_{th})}}{1-e^{-\beta}} \right], g_{th} < g \le g_{max} \end{cases} \quad (1)$$

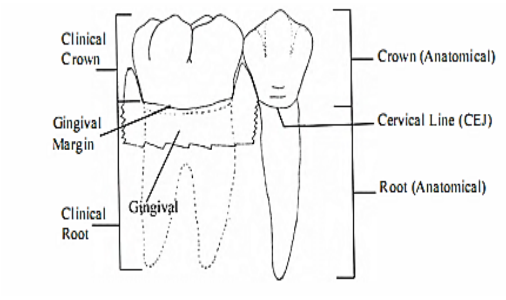


Figure 6. Mesiodistal neck [3].

$$gTH = \lceil 255 * (g_{th} - g_{min})/(g_{max} - g_{min}) \rceil \quad (2)$$

$$\begin{aligned} g_{bb} &= \min_{\langle g \rangle} S_{\mathrm{i}}(g) \geq \kappa_1 \\ g_{ba} &= \min_{\langle g \rangle} S_{\mathrm{i}}(g) \geq \kappa_2 \end{aligned}, 0 < \kappa_1 < \kappa_2 \quad (3)$$

Different from the previous methods that only use the threshold value for handling the problem of dental works which have a high intensity, in this method the problem can be solved by using equation(1) where α as the compression factor will make changes to the pixels that have intensity under $\boldsymbol{g_{th}}$ and β as an expansion factor will process the pixels that have intensities above $\boldsymbol{g_{th}}$ so as to obtain the results of the image with better contrast.

Furthermore, the value of α, β and g_{th} are obtained from fuzzy rules (Figure 3). The model of fuzzy membership function is obtained by several experiments that this model gives the best result of contrast enhancement according to dataset that we use. This rule assumes that the image with go-od contrast has a lower bound g_{bb} located in a dark region and the upper bound g_{ba} located on the bright region of the gray scale. Thus obtained g_{th} value in the range of [0, 1] which is defined by g_{th} *(norm)*. This value is located between g_{bb} and g_{ba}. Before being used in equation (2), value of g_{th} is converted by using $g_{th} = [g_{bb} + g_{th}\,(norm) * (g_{ba} - g_{bb})]$.

In Table 1 describe the determination of the values of α, β and g_{th} based on fuzzy rules. Then contrast stretching is performed by using parameter values which have been obtained. The result show teeth image has better contrast than before (Figure 4). Contrast stretching phase that proposed in this study, makes the intensity of the teeth look more clearly than the gums. Then it is followed by using Contrast Limited Adaptive Histogram Equalization (CLAHE). Morphology operation then performed on the image of the flattening contrast. The last step is adding contrast image enhancement result with its top-hat. Then the result of morphology operation is obtained (Figure 5). The image shows the results of image preprocessing ready for binarization.

Segmentation

Otsu thresholding segmentation method is used to change the gray scale image into a binary form. This process aims to determine the object and background. Some morphological operations such as dilation, closing, opening and erosion performed sequentially in order to maximize the cutting line between the teeth. So it can provide more optimal binarization results. This step begins with jaw separation process using horizontal integral projection technique. The separation of each tooth is done by using the vertical integral projection and using connected component to obtain each region as a separate tooth.

Teeth Classification and Numbering

After getting a separate binary image of the teeth to one another, the next step is to perform the classification numbering process every tooth in the image. Feature extraction is performed before classifying and give number the teeth. In this paper, tooth area and its mesiodistal neck are used as feature. After getting data of features, the process of classification and numbering are done respectively. Further details will be explained.

Mesiodistal Neck Detection

Mesiodistal is the boundary between the crown and root (Figure 6). Mesiodistal width of the smallest size that is located on the crown of the tooth while the size of the largest width is at the root. The width of the teeth tends to be stable, start from the third parts down, and began to change in the mesiodistal.

After obtaining the region of each tooth, mesiodistal width can be determined by equation(4) to obtain a wide set of values that would be selected as the mesiodistal.

$$Neck[i] = Max(y_i) - Min(y_i), \quad 1 \leq i \leq \max row \quad (4)$$

i is the index line on the image, the maximum and minimum column index on an *i-th* row, shown with *Max(yi)* and *Min (yi).* Mesiodistal value and its position are stored to describe the neckline teeth as a visual representation.

Classification

In this study, Support Vector Machine (SVM) linearly used to classify the teeth into M (molar) or P (premolar). The basic concept from the SVM is to find separator function (classifier) that optimize the separation of the two data sets from the two different classes, then it will be tested to ascertain whether the data really has been separated.

Data is assumed to be a data that can be separated in a linear SVM and then being tested on the next stage whether the data is completely separated linearly. Generally SVM is described as a vector that satisfies the equation $w.x_i + b = 0$, where w a normal vector, x_i is *i-th* data and b/‖w‖ is the distance between the hyper plane to the origin of the data [4].

The first step is to determine the classification linear SVM training data by selecting N of data randomly from the entire dataset. Next, find w* and $b*$ optimal which is defined by the following equation(5).

$$w^* = \sum_{i=1}^{n} a_i \, y_i x_i \quad (5)$$

$$w^* = \frac{1}{N}\sum_{s\in S}^{n} y_s - \sum_{m\in S}^{n} a_m \, y_m x_m . x_s \quad (6)$$

where α is the Lagrange multiplier so $\sum_{i=0}^{n} a_i - (1/2) a^T B a$ can be maximized, constraints that must be met is $a_i \geq 0$ and $\sum_{i=0}^{n} a_i y = 0; B$ is a matrix where $B_{ij} = y_i \, y_j \, x_i \, x_j$ and S sets from the support vectors that have a value $a_i > 0$.

The optimal w* and $b*$ have been obtained, forming the equation $w^*.x + b^* = 0$, so that the two sets of data (molar or premolar) can be separated to the maximum (the most distant position between the two data). Training is a support vector data *(x,y)*, with $w.x + b = 1$ is 1 class, $\text{w.x} + \text{b} = -1$ is -1 class, and hyper plane $\text{w}^*.\text{x} + \text{b}^* = 0$ is bounds for classification decision-making. Each of training data expressed in tuple (x_i, y_i) with $(i = 1, \ldots, N)$. Where $x_i = (x_{i1}, x_{i2}, \ldots, x_{id})^T$ is feature vector (wide area teeth, mesiodistal width of the teeth)^T and $y_i \in \{1, -1\}$ is the class from the teeth, ie M (Molar) or P (Premolar).

The next step is to conduct testing process. This process is a molar or premolar labeling by determining the value from the results of mapping any stated data test. If any data test valued $y' > 0$ then it will be grouped into class molar and premolar group otherwise would be. Mathematically defined $y' = sgn(w^*.x' + b^*)$ is a sign function and *x'* is the test data.

Teeth Numbering

Teeth numbering process is based on rules of international numbering (1 to 32) by matching the pattern of ground truth with the patterns obtained in the classification process. Further checks whether the teeth that have been obtain is forming sequential pattern or not. For example, if MPM is not a valid pattern, so the most similar ground truth pattern will be used.

3. Results and Analysis

This study has been tested by using 15 teeth images with different characteristics. 6 teeth data is bitewing and the rest teeth data is 9 panoramic. In data tested, there are 112 data of single teeth in total, where 60 types of data are molar teeth and 52 types of data are premolars. The dataset that we used is representing several images with different contrast conditions.

Segmentation Result

Based on the experiment result, it can be concluded that the segmentation algorithm used in this study is quite good in accordance with the level of accuracy of the segmentation that has been produced. In Table 2 we present the segmentation result from the result of contrast enhancement using the

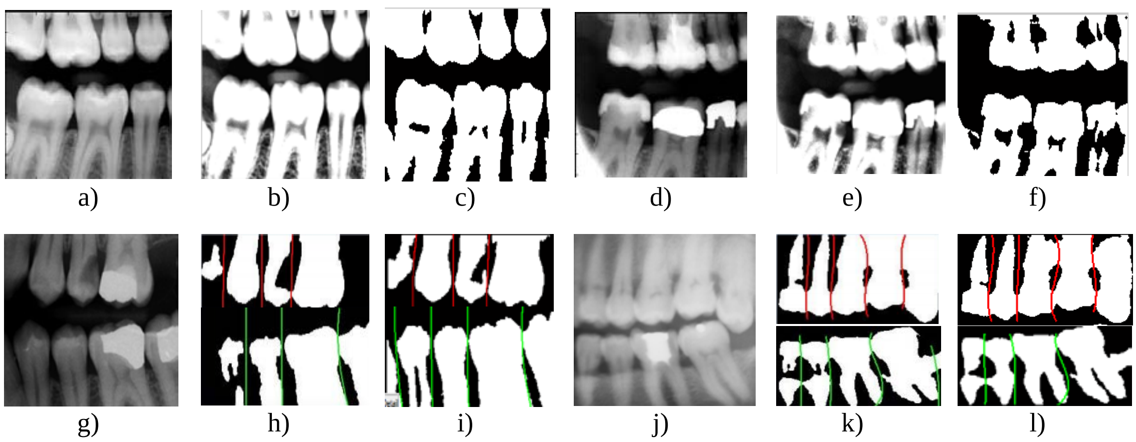


Figure 7. Segmentation result, a) , d), g) and j) Original image. b) and e) Result of preprocessing. c) Normal segmentation result. f) Half-failed segmentation result. h) and k) Segmentation and teeth separation result of previous method [5]. i) and l) Segmentation and teeth separation result using proposed method.

TABLE 2
COMPARISON OF THE ACCURACY OF SEGMENTATION RESULT

No	Image	Actual Number of Teeth	Previous Method [5]	Accuracy	Proposed	Accuracy (proposed)
1	Bit1_Rigth.tif	5	5	100%	5	100%
2	Bit2_Right.tif	7	7	100%	7	100%
3	Bit3_Left.tif	6	5	83%	5	83%
4	Bit4_Right.tif	7	7	100%	7	100%
5	Bit5_Left.tif	7	6	85%	7	100%
6	Bit6_Right.tif	6	4	66%	5	83%
7	Pan1_Left.tif	8	8	100%	8	100%
8	Pan1_Right.tif	8	8	100%	8	100%
9	Pan25_Left.tif	9	8	88%	9	100%
10	Pan25_Right.tif	9	9	100%	9	100%
11	Pan34_Left.tif	8	8	100%	8	100%
12	Pan34_Right.tif	7	7	100%	7	100%
13	Pan50_Left.tif	9	9	100%	9	100%
14	Pan70_Left.tif	8	8	100%	8	100%
15	Pan70_Right.tif	8	8	100%	8	100%
	Total	112	107		110	
	Average			95%		98%

previous method [5] and our proposed method. Our proposed method can improve the results of part of teeth that can be detected.

This result can be obtained because of the image enhancement process in the form of contrast enhancement. The results from the image enhancement and then improve the accuracy of segmentation results. Although a better segmentation results can be obtained, there are also parts of the teeth image still cannot be segmented perfectly (half-failed segmentation) (Figure 7). This was due to the poor of tooth structure and the intensity of teeth and gums are too closed.

Classification and Numbering Result

The classification results obtained by the experiments showed that the accuracy of classification result is quite good. We used confusion matrix to evaluate classification result. The accuracy of classification can be calculated by using equation(7). *TP* and *TN* are the number of predictions that were correct. *FP* and *FN* are the number of predicttions that were incorrect.

$$Accuracy = \frac{TP+TN}{TP+FP+FN+TN}. \quad (7)$$

From 15 input images consisting of 112 single teeth, there are 99 teeth or 88% that classified correctly. The result showed that our method can classify teeth that cannot be classified in the previous approach. Detailed result can be seen in Table 3. In addition, we also found cases in which our system is only able to classify partly of the existing teeth on the input image. Because it only detects 4 from 5 teeth that should be detected by the system (Half-failed classification) (Figure 8).

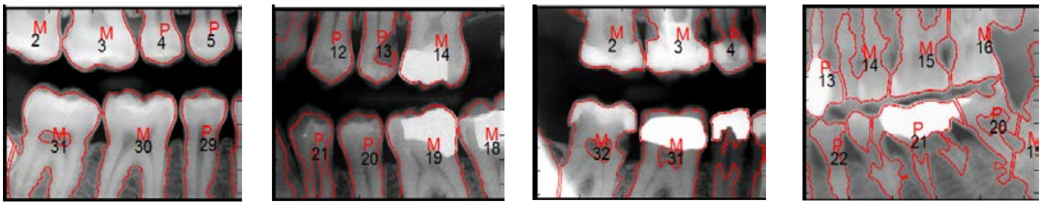
TABLE 3
CONFUSION MATRIX OF CLASSIFICATION RESULT

		Actual Class	
		Molar	Premolar
Prediction Class	Molar	55	5
	Premolar	8	44

Because of the ambiguous patterns which affect error in numbering process. We use an algorithm that can improve the accuracy of the classification. When found a strange pattern, for example as PMPMM, the pattern will change into PPMMM. Based on the results of tests carried out, from the 112 teeth that used, the accuracy of the numbering reaches 73% or 82 teeth. Detailed result can be seen in Table 4.

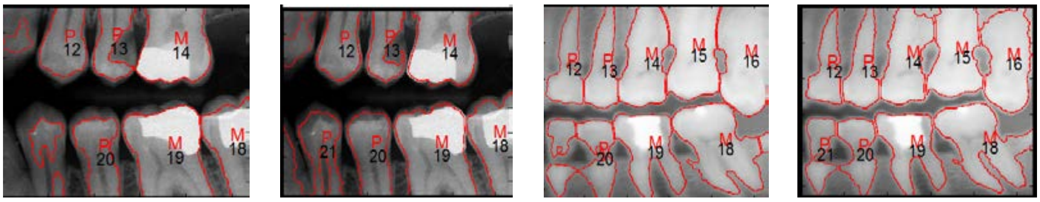
The result of the classification can be achieved due to the segmentation results obtained are also quite good. If the result of the segmentation and teeth separation is not accurate then it will affect the value of acquired features to classify. Contrast enhancement that proposed in the form makes the intensity between the gums and teeth can be distinguished well. So, it can be segmented globally.

Based on our analysis, there are several factors that resulted in the failure classification and numbering are: 1) the intensity of the teeth and gums that tend to be the same, resulting in part of the tooth is considered as gums (Figure 8.c); 2) corrupted structure/irregular teeth. When separating the teeth using horizontal and vertical integral projection that based on the extreme point which is considered as the gap between the teeth. It will increase the potential of teeth separation error (Figure 8.d). Because the extreme point found at the center of teeth resulting the sepa-ration process on the part that is not supposed. Thus, final result is tooth that is not complete. It also makes the re-



a) b) c) d)

Figure 8. Classification and numbering case. a) and b) Normal classification, c) and d) half-failed classification.



a) b) c) d)

Figure 9. Classification and numbering result. a) and c) Result of previous method [5], b) and d) result of proposed method.

TABLE 4
NUMBERING RESULT

Actual Number of teeth	Numbering result	
	True	False
112	82	30

sults of the classification and teeth numbering that we obtained slightly decree-sed compared to the previous method.

Misclassification occurs as a result from the inaccurate segmentation. This of course affects the feature extraction process that resulted in the value of features that are not appropriate. As a result, there was an error in determining the classification of types of teeth. But overall classification results can be quite accurate because the majority of the input image can be recognized properly (Figure 9).

4. Conclusion

We presented a new contrast enhancement to improve image contrast of dental radiographs image. Our method can handle contrast problem in bitewing and panoramic dental images. Besides that, the method is quite simple but it can give good contrast enhancement results that improve the accuracy of segmentation results. Our method include: 1) parameter sigmoid transform contrast enhancement, 2) contrast limited adaptive histogram equalization and 3) morphological operation (top-hat).

After contrast enhancement, teeth segmenting and separating process using horizontal and vertical integral projection, tooth area and mesiodistal feature extraction, classification and numbering are perform respectively.

The results show: 1) the proposed algorithm can improve the segmentation result accuracy, 2) it can segment dental images that have low contrast and uneven illumination and 3) the accuracy rate of classification and numbering are 88% and 73%, respectively.

For future work, we plan to build a robust method that able to perform better contrast stretching due to the contrast problem is still an issue that needs to be solved.

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